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THE SWEETLAND CREEK BEDS[1]

In Muscatine, Bloomington, Sweetland, and Montpelier townships, of Muscatine county, Iowa, some argillaceous beds are frequently found overlying the Cedar Valley limestone These contain a fauna quite different from that of the latter, and are unconformable with this as well as with the Coal Measures above. For reasons which will presently appear it is proposed to call them the Sweetland Creek beds.

Typical exposures.—Following the north bluffs of the Mississippi westward, the first occurrence of these beds is to be seen in the bank of a creek which comes down from the north, just east of the town of Montpelier. About twenty rods north of the bluffs the basal sandstone of the Coal Measures rests on some olive-gray shale, with green bands, rising about three feet from the bed of the stream in the right bank. This shale is altogether unlike the dark shale of the Coal Measures in appearance. The layers are more even and uniform. An unconformity between the two is also evident, and the lower formation soon disappears. In the river bluff the same creek is undermining a cliff of Coal Measure rock, which rests on the Cedar Valley limestone for the greater part of its length, but at the south end the base of the Coal Measures rises somewhat abruptly, first on an eroded slope of the limestone, and then over some decayed yellow clayey beds which intervene and run up ten or twelve feet above the limestone. The present condition of the bank does not afford an opportunity to closely study the nature of the clay beds, but in all probability they belong to the same strata as the shale above.

To the west of the town, a short distance up in Robinson Creek, and just northwest of Mr. G. W. Robinson's residence, some green clay is seen in the south bank of the creek, appar-

[1] Published by permission of the State Geologist of Iowa.

ently resting on the eroded surface of the Cedar Valley limestone. At the base of this clay there is a thin layer of more stony material, and this contains specimens of *Ptychtodus calceolus* and other small fish teeth. This is the basal layer of the Sweetland Creek beds. About one half mile farther up the same creek near the north line of section 23, in Montpelier township, just below a small fall in the creek, the following section is seen.

Number		Feet
13.	Coal Measures.	
12.	Dark bituminous shale with two or three bands of green shale; the dark next the green exhibiting a complex network of thread-like green extensions from ½ to 2^{mm} in thickness, lying approximately parallel with the bedding. Occasional lingulas found	1
11.	Dark bituminous shale with small spheroidal crystalline nodules of pyrites, occasional lingulas and *Spathiocaris emersoni* - -	2
10.	Concealed (next number a few rods farther down) - - -	2 ?
9.	Light greenish shale - - - - - - - - - -	1
8.	Dark olive-gray shale - - - - - - - - -	⅔
7.	Green shale - - - - - - - - - -	⅔
6.	Greenish calcareous shale, almost stony, containing cylindrical or flattened fucoid markings slightly more greenish than the matrix	⅚
5.	Dark gray shale - - - - - - - - - -	1
4.	Grayish-green pyritiferous rock with minute fragments of unrecognizable fossils - - - - - - - - - -	¼
3.	Dark gray shale - - - - - - - - - -	¼
2.	Greenish-gray somewhat stony shale exhibiting concretionary conchoidal fractures when weathered - - - - -	¼
1.	Greenish-gray argillaceous and pyritiferous fine-grained dolomitic rock in layers a few inches in thickness, with fucoid impregnations or markings like those in number 6, ¼ inch in diameter -	1⅔

At the south end of this outcrop there is a small displacement in the ledges, which, dipping at a considerable angle south of it, soon disappear under the Coal Measures. The displacement is no doubt local and probably due to the falling in of some cavern in the underlying limestone.

Westward for the next three miles these beds do not appear, although the contact between the Coal Measures and the Cedar Valley limestone frequently comes into view. In the Pine Creek

basin they must have been removed by erosion previous to the deposition of the Coal Measures. Their next appearance is in Schmidt's run, about a mile east from the railroad station at Fairport. Just north of the wagon road under the bluffs they may be seen in the left bank of the run. There are several outcrops farther up, and the following section was made out, unconformably overlaid by the Coal Measures.

Number		Feet
4.	Dark, almost black shale, with green seams from one to four inches thick, near which the darker shade exhibits a net work of filamentous extensions of green clay	7
3.	Greenish light colored shale	3½
2.	Greenish stony and hard shale	½
1.	Greenish gray soft shale	1½

Just west of the railroad station at Fairport, where a wagon road follows a ravine up the bluff, this ravine exposes the following section.

Number		Feet
7.	Coal Measures resting unconformably on the numbers below.	
6.	Weathered shale of alternate light and dark layers	5
5.	Dark gray shale	5
4.	Grayish-green shale with two bands of darker shale in part perforated by coarse curving filaments or cylinders of green shale	3
3.	Concealed	2 ?
2.	Dark gray shale with curving cord-like cylinders of green shale about ⅙ inch in diameter	3
1.	Greenish argillaceous dolomite in layers about 6 inches in thickness	1

In a small ravine which comes down from the west side of Wyoming Hill there is seen under and north of the wagon bridge about eight feet of gray and green shale with some stony layers. The Cedar Valley limestone comes out in the river bank just below and the Coal Measures overlie the exposure, rising about 100 feet above it.

Along Sweetland Creek the relation of these beds to the formations above and below them is better exhibited than at any other place in the county. About one-third of a mile north from the river bank they come out into view on both sides of

the creek, and they are also seen in a small tributary which runs into the creek from the east. Combining all the exposures at this point the following succession of separate layers is evident.

Number		Feet
11.	Dark gray bituminous shale with one or two thin green bands about four feet below the highest exposure. Occasionally small flat concretions of pyrites are seen. Next the green layer the shale is dark filled with a maze of fine green filamentous lines. Drift overlies	8
10.	Dark shale containing lingulas, *Spathiocaris emersoni, Rhynchodus,* and a fossil resembling *Solenocaris strigata.* This number is continuous with No. 11	1½
9.	Greenish clay with flat concretions of iron pyrites frequently having white stony lamellar extensions from the margin	3
8.	Dark shale	⅔
7.	Greenish stony shale with a conchoidal concretionary fracture,	⅓
6.	Hard light grayish-green shale with white flattened cylindrical fucoid concretions of a concentric structure in horizontal positions	¼–½
5.	Greenish argillaceous or arenaceous fine-grained dolomite in ledges from 4 to 10 inches in thickness, with occasional lingulas and a fragment of a cast of a gasteropod near the base, frequently exhibiting small cylindrical concretionary impregnations of a deeper green, and occasionally impressions of plant-like fibrous structure covered with a thin layer of bituminous material	3
4.	Greenish shale	1½
3.	A stony seam filled with finely granular pyrites and occasionally showing larger lumps of the same mineral in one instance associated with plant-like fibrous impressions, frequently containing rounded worn fragments of fish teeth	1/12–¼
2.	Green hard shale	⅔
1.	Greenish stony layer with frequent, mostly rounded, fragments of *Ptychtodus calceolus*	⅓

Under the lowermost layer containing fish teeth the uneven surface of the upper ledges of the Cedar Valley limestone is seen, and at least eight feet of this rock is exposed. In some of the shallow depressions in its upper surface a seam of black bituminous material is found. At one point this forms a layer two inches in thickness. Near the south end of the exposure farthest down the creek the upper beds come down over the

uppermost ledge of the limestone, which runs out as if worn away. The surface of the limestone has been partly uncovered by the creek. It is brown in color, uneven from erosion and frequently studded with nodules of iron pyrites or covered by a continuous incrustation of the same mineral. In the west bank of the creek the basal sandstone of the Coal Measures overlies the eroded edges of numbers 6, 7, and 8 in the above section, which rise under it in a hillock. In the gully to the east the section is continued higher up and the Coal Measures do not appear. Some distance farther up Sweetland Creek they are again seen unconformably overlying the dark gray shale in the east bank, with erosion contours extending down three feet into the lower formation. At this place the basal conglomerate contains rounded lumps of the dark shale, three or four inches in diameter. Still farther up the creek the darker shale corresponding to number 11 in the above section appears at several places in the bed of the stream, rising in one instance about five feet in the bank. The last seen is about one hundred paces south from the wagon bridge near the north line of section 27. In each of these places the characteristic green layers with their accompanying network of green threads in the confining dark shale may be seen.

About three fourths of a mile west of Sweetland Creek, near the east line of section 28, in Sweetland township, a smaller stream exposes the following section.

Number		Feet
5.	Coal Measures.	
4.	Alternate layers of dark and greenish shale - - - - -	4
3.	Fine grained, light yellowish-gray, impure dolomite in thin ledges	2½
2.	Greenish shaly rock with a thin, harder layer below - - -	2¼
1.	Upper ledges of the Cedar Valley limestone, ferruginous and worn superficially - - - - - - - - - -	1–2

In Camhel Run, which comes down to the river through the northwest corner of section 21, in the same township, a similar succession of layers is seen at the point where the stream passes the line of the river bluffs. The following section appears very clearly.

Number		Feet
11.	The base of the Coal Measures.	
10.	Dark gray shale with lingulas near the base	3
9.	Greenish shale	3½
8.	A layer of harder, almost stony shale	½
7.	Greenish-gray shale weathering with a conchoidal fracture into small spheroidal nodules and chips	1±
6.	Grayish, fine grained, impure dolomite	1½
5.	Greenish shale	1±
4.	A thin and stony, in places highly pyritiferous seam, associated with small selenite crystals when decayed, in places almost filled with rounded specimens of *Ptychtodus calceolus*	$\frac{1}{10}-\frac{1}{5}$
3.	Greenish shale	½–1
2.	Greenish fine-grained rock with fish teeth	1/6–¼
1.	Upper ledges of the Cedar Valley limestone with a slightly eroded surface, frequently covered with pyrites.	

Number 10 in the above is seen in two or three places farther up in the creek, but it soon disappears under the base of the Coal Measures.

Along Geneva Creek, in the northwest quarter of section 29, in the same township, the basal layers of the preceding sections are seen in the bed of the stream opposite the Geneva schoolhouse, and below the wagon bridge. The main stony ledge forms the bed of the creek for a distance of ten or twenty rods a quarter of a mile farther up. About half a mile north of the schoolhouse the shale above this ledge rises some six feet in the west bank, and is overlaid by the basal conglomerate of the Coal Measures, from which a small spring issues. Combining these exposures the succession of the layers seen may be given as in the following section.

Number		Feet
13.	Basal conglomerate and sandstone of the Coal Measures.	
12.	Dark gray and ferruginous, evidently somewhat disintegrated dark shale	$\frac{4}{5}$
11.	Light greenish-gray shale	$\frac{4}{5}$
10.	Dark lavender colored shale	1⅙
9.	Green shaly rock	½
8.	Concealed	?
7.	Green rock in even thin layers with regular vertical rather equidistant joints	1½

Number		Feet
6.	Concealed	?
5.	Greenish shale (opposite the schoolhouse)	1
4.	Pyritiferous green stony layer with cylindrical straightish fucoid impregnations	4/6
3.	Green shale	1
2.	A conglomerate of fish teeth, containing *Ptychtodus calceolus* and *Synthetodus* frequently in a worn condition and imbedded in a greenish argillaceous fine-grained dolomite	1/4
1.	Beds of the Cedar Valley limestone containing large fragments of Stromatopora, with the upper surface unevenly eroded.	

From this point westward no more is seen of the beds under consideration until we come to East Hill, in Muscatine. Under the south bluff of this hill the railroad bed has been excavated in the upper dark shale seen in the foregoing sections. These rise here about thirty feet above the bed of the road, and they have been so disposed to slip in the bank, that piles and a stone-wall have for many years been needed to keep the embankment from coming down on the track. These were removed late last fall and the face of the embankment was cut away several feet. This work left the shale well exposed. The section above and below the railroad bed is as follows.

Number		Feet
2.	Dark or gray bituminous shale, with three parallel bands of green shale a few inches in thickness and about three or four feet apart, weathering into fine chips of a yellowish light gray color, containing small flat concretions of pyrites, joints in some of the freshly exposed shale filled with numerous small crystals of lenite disposed in branching patterns, the basal part containing sea lingula and exhibiting the peculiar network of green thread-like extensions observed in previous sections near the transitions to green shale	36
1.	Green shale	2

The top of number 2 is unconformably overlaid by the Coal Measures, and has evidently been weathered previous to their deposition. Below number 1 the section is concealed in the river bank. The base of this layer is about ten feet above low water. There is little doubt that it is the equivalent of number

9 in the Sweetland Creek section, and the lower layers of these beds may possibly all have been exposed above water at this point before the railroad embankment was made. As these lower layers aggregate about seven feet in thickness at other places, it will be noticed that the extreme thickness of the whole formation at this place is about forty-five feet. This is the greatest thickness that has been seen anywhere in the county.

Just above the wagon bridge which crosses Mad Creek near the center of the northwest quarter of section 24 in Bloomington township, some ledges equivalent to numbers 6, 7, 8 and 9, in the Sweetland Creek section appear in the bank of a tributary from the east. Again in the creek running east through the north half of the northwest quarter of section 26 in the same township some thin ledges of rock and some green shale corresponding to numbers 3, 4, and 5 in Sweetland Creek come into view from under some Coal Measure beds.

Geographical distribution.—So far as known, the above places include all the exposures of the Sweetland Creek beds in the county. There is good reason to assume that they underlie the Coal Measures in most of Muscatine, Bloomington, and Sweetland townships, and that scattered outliers occupy the same position in the east half of Montpelier township. In all probability their outcrop in the river bluff is continuous from Wyoming Hill to Muscatine, though mostly concealed by the talus under the bluffs.

General section.—The separate layers and ledges of the formation have a remarkably uniform development, varying but slightly in different places. The basal layer, though only about three inches in thickness, can always be recognized in its place, and invariably contains the characteristic fish teeth. From six inches to a foot above this layer there is a pyritiferous stony seam from one-half to two inches in thickness, and this is readily identified in all the creeks in Sweetland township where the lower part of the section appears. The peculiar maze of green threads which extend into the dark shale where this comes into contact with green layers have been observed in almost every case where

they are due in the section, all the way from Muscatine to Montpelier. It is therefore no very difficult task to combine the local outcrops into a general section.

GENERAL SECTION OF THE SWEETLAND CREEK BEDS

Number		Feet
7.	Dark bituminous shale, occasionally containing small flat concretions of iron pyrites, with three thin bands of greenish shales respectively about 5, 9, and 12 feet from the base	33
6.	Dark shale, with thin seams of blue shale, the dark containing two species of lingula, *Spathiocaris emersoni*, *Rhynchodus*, and a fossil resembling *Solenocaris strigata*	3
5.	Greenish shale, with occasional stony layers, containing flat concretions of pyrites frequently bordered by lamellar marginal extensions of a white dolomitic material	3½
4.	Alternating layers of greenish stone and green and dark shale, the latter in part containing a network of thread-like extensions of the former. The green shale has elongated flattened concretions resembling fucoid growths and lying parallel with the bedding. The stony layers are frequently charged with small grains of pyrites and contain minute fragments of fossils	2
3.	Greenish fine-grained argillaceous magnesian limestone impregnated with iron pyrites and calcium phosphate, in ledges from 4 to 10 inches in thickness, with cylindrical fucoid impregnations slightly more greenish than the matrix and from 3 to 6 millimeters in diameter, containing two species of lingula, a fragmentary cast of a helicoid gasteropod, and imprints of some fibrous structure like that of some plant stem	3½
2.	Hard greenish-gray shale, with a stony pyritiferous layer that contains fish teeth and impressions of vegetable tissue about 10 inches from base	3
1.	Argillaceous dolomitic stony layer containing *Ptychtodus calceolus* and other forms resembling *Synthetodus*	¼

Lithological peculiarities.—The greenish ledges turn grayish-yellow on weathering. The main stony ledge, number 3, often protrudes as a shelf over the clay below it, which is more easily removed by erosion. In two instances an efflorescence of epsomite was noticed forming on the face of the clay thus protected from rain by the overhanging rock. The material found in the shells of the lingulas of this ledge was unaltered, but

in one instance slightly dissolved away. The tubular impregnations in the stony layers of the formation appear to be marked off from the mass of the rock so as to sometimes weather out like casts of fucoid stems. In other instances they appear like slightly more colored parts of the rock. The thread-like extensions of green clay which form a network in the dark shale at some horizons where it comes in contact with the lighter shale vary in coarseness at different places. There is nothing to indicate a structural boundary between the green in the threads and their dark matrix, and there is hardly anything to suggest that they have an organic origin. It seems more likely that they have resulted from some progressive change in the mineral nature of the shale. Excepting the lingulas, the fossils which occur in the layer numbered 6 in the general section are all of a black and bituminous substance, which is apt to break and fall out in drying, leaving only a mold. The dark shale in numbers 6 and 7 is fine and very uniform in character. Occasionally it is difficult to distinguish from the Coal Measure shale, but the latter usually contains small mica scales, which are absent from the former. Where not weathered, these beds contain a considerable amount of bituminous material, which on distillation yields inflammable gas and oil. The several layers of the formation have been examined for phosphate by Dr. J. B. Weems, who finds 2.01 per cent. in number 7, 1.94 per cent. in number 6, 2.09 and 2.18 per cent. respectively in two analyses of material from number 5, 3.18 per cent. in number 4, 6.82 and 5.29 per cent. respectively in two analyses of material from number 3, 5.43 per cent. in number 2, and 4.86 per cent. in number 1.

Structural Relations.— As already shown, a pronounced unconformity separates this formation from the overlying Coal Measures. The erosion interval preceding the deposition of the latter has left its marks, not only in the reliefs which extend from the top of these beds to a considerable distance below their base into the underlying limestone, but also in the weathering of the Sweetland Creek beds, especially where these rise

high. In such places the lamination appears indistinct, and the shales are oxidized and leached. After the deposition of the Sweetland Creek beds they were raised and subjected to erosion and sculpturing, which no doubt removed the greater part of them. Only remnants are left. Then, again, the land was submerged, and the topography just sculptured was covered over by the variable shore deposits of the Coal Measures.

It has also been shown that there is an unconformity with the underlying Cedar Valley limestone. But this unconformity indicates altogether different conditions. The upper formation is, in this case, not a shore deposit. The basal member of the Sweetland Creek beds is a thin layer of argillaceous dolomite containing no littoral detritus, and it is unusally uniformly developed, though only two or three inches thick. It is a sediment made in the sea at such a slow rate that the teeth of dying fishes accumulated rapidly enough to make at one place as much as one fourth of its bulk. This layer follows the small inequalities in the surface of the lower rock like a mantle. None of these are very high or deep. On a distance of a few rods none appear to exceed two feet in vertical extent. Near the Geneva school the basal tooth-bearing layer appears to occupy a place eight feet lower than the highest ledge in an abandoned quarry close by. The surface of the limestone is, however, plainly eroded and apparently to some extent oxidized. In the east bank of Sweetland Creek the highest ledges of the limestone run out to the south, and the overlying formation comes down over their beveled edges. An unconformity of this kind is most likely caused by subaqueous erosion, due to marine currents, followed by renewed sedimentation in the same sea. Such events may have been accompanied by an approach of the shore line. This is, perhaps, indicated by the presence of faint traces of vegetation in the later member in this case. But at the very beginning of the second accumulation the shore was not near enough to leave a trace of anything coarser than clay. Even this was scarce at first, when calcareous sediments predominated. The persistence of each thin layer over distances of several

miles goes to show that the conditions under which they were laid down were uniform over wide areas, and such conditions are not to be found in the proximity of the shore line. Everything considered, this unconformity was most likely caused by changed conditions in the sea and its currents, in all probability consequent upon some orogenic movements affecting the ocean basin.

Fossils.—The fossils so far found in this formation are few, but they are many enough to indicate that it must be referred to the Upper Devonian, or the Chemung. The fibrous plant-like impression from number 3 was found extending over a slab a foot long and about three inches wide. In the pyritous layer in number 2 there was a similar, much smaller, impression. The mold in both instances was covered by a bituminous crust an eighth of an inch in thickness. In this no organic structure could be detected. The lingulas which occurs in numbers 3 and 6 have been submitted to Dr. Charles Schuchert, who says that one species is apparently identical with an undescribed species, from nodules in the "Black Shale," or the Genesee; one is related to *L. melie* Hall, from the Cuyahoga shale; and another to *L. nuda* Hall, from the Hamilton. The author has also observed one lingula in number 6, which resembled *L. subspatulata* M. and W. Some small bilobate fossils from the same number in the general section have been examined by Dr. J. M. Clarke, who has reported that they are identical with *Spathiocaris emersoni* Clarke. This fossil occurs in the Portage group in New York, and has not previously been reported from the West. In the same layer the author found one fossil which resembled *Solenocaris strigata* Meek. This form is known to occur in the "Black Shale" of the Ohio valley. The cast of a gasteropod, found in the stony ledge number 3, was too fragmentary for more exact determination. Dr. C. R. Eastman has examined all the fish remains found, and states that the greater number of the teeth from numbers 1 and 2 are *Ptychtodus calceolus* M. and W. He finds them on the average smaller than usual, but in other respects perfectly like the type. He also reports that there are several other forms of flat, crushing teeth, which are allied to

Synthetodus from the State Quarry fish bed in Johnson county. From the bituminous dark shale, number 6, he identifies a Rhynchodus, related to *R. excavatus* Newb., from the Hamilton in Wisconsin.

LIST OF FOSSILS IN THE SWEETLAND CREEK BEDS

Impression of plants.	
Lingula, sp. undet.	Identical with one from the Black Shale
L. cf. melie Hall	Cuyahoga Shale
Lingula, cf. nuda Hall	Hamilton
Lingula subspatulata M. and W. (?)	Black Shale
Spathiocaris emersoni Clarke	Portage Shale
Solenocaris strigata Meek (?)	Black Shale
Gasteropod	
Ptychtodus calceolus M. and W.	Hamilton and State Quarry Beds
Synthetodus	State Quarry Beds
Rhynchodus, cf. excavatus Newb.	Hamilton

Additions will no doubt be made to this list. As it is, it indicates a correlation with the Upper Devonian of New York, and more particularly with the Devonian Black Shale of the interior, which also is regarded as a part of the Upper Devonian. To this shale it shows another resemblance in having the basal layers stony and containing a comparatively high per cent. of calcium phosphate, while the upper part is a black shale. It will be remembered that in Perry and Hickman counties in Tennessee the Black Shale changes downward into the phosphate rock.[1]

This comparison may be better shown in tabular form.

RELATION OF DARK SHALE TO PHOSPHATE BEARING ROCK IN IOWA AND IN TENNESSEE

Iowa		Tennessee
Bed No. 7 contains 2.01 % of phosphate	Dark Shale	Black Shale containing little or no phosphate
" " 6 " 1.94 % " "		
" " 5 " 2.13 % " "		
" " 4 " 3.18 % " "	Variable beds	Light gray to bluish-black phosphate rock, with disseminated pyrites
" " 3 " 6.05 % " "	Greenish gray pyritiferous rock and shale	
" " 2 " 5.43 % " "		
" " 1 " 4.86 % " "		

[1] See the Tennessee Phosphates, by C. W. HAYES, Seventeenth Ann. Rep. U. S. Geol. Surv., Part II.

The indicated correlation appears all the more probable, as there exists under the phosphate-bearing rock in Tennessee an unconformity, which is believed to be due "not to the existence of a land area and subaërial erosion, but rather to non-deposition, by reason of strong marine currents."[1] The renewal of the conditions of sedimentation in the paleozoic sea in the late Devonian age may not have been quite simultaneous in the two localities, though nothing is known to indicate the contrary, but there seems to have been at any rate a parallel in the sequence of events.

J. A. UDDEN.

[1] Loc. cit., p. 534.